Processing Satellite Imagery To Detect Waste Tire Piles

Less time is needed for searching for previously unidentified piles.

Ames Research Center, Moffett Field, California

A methodology for processing commercially available satellite spectral imagery has been developed to enable identification and mapping of waste tire piles in California. The California Integrated Waste Management Board initiated the project and provided funding for the method's development. The methodology includes the use of a combination of previously commercially available image-processing and georeferencing software used to develop a model that specifically distinguishes between tire piles and other objects. The methodology reduces the time that must be spent to initially survey a region for tire sites, thereby increasing inspectors' and managers' time available for remediation of the sites. Remediation is needed because millions of used tires are discarded every year, waste tire piles pose fire hazards, and mosquitoes often breed in water trapped in tires. It should be possible to adapt the methodology to regions outside California by modifying some of the algorithms implemented in the software to account for geographic differences in spectral characteristics associated with terrain and climate.

The task of identifying tire piles in satellite imagery is uniquely challenging because of their low reflectance levels: Tires tend to be spectrally confused with shadows and deep water, both of which reflect little light to satellite-borne imaging systems. In this methodology, the challenge is met, in part, by use of software that implements the Tire Identification from Reflectance (TIRe) model. The development of the TIRe model included incorporation of lessons learned in previous research on the detection and mapping of tire piles by use of manual/visual and/or computational analysis of aerial and satellite imagery.

The TIRe model is a computational model for identifying tire piles and discriminating between tire piles and other objects. The input to the TIRe model is the georeferenced but otherwise raw satellite spectral images of a geographic region to be surveyed. The TIRe model identifies the darkest objects in the images and, on the basis of spatial and spectral image characteristics, discriminates against other dark objects, which can include vegetation,

some bodies of water, and dark soils. The TIRe model can identify piles of as few as 100 tires. The output of the TIRe model is a binary mask showing areas containing suspected tire piles and spectrally similar features. This mask is overlaid on the original satellite imagery and examined by a trained image analyst, who strives to further discriminate against non-tire objects that the TIRe model tentatively identified as tire piles. After the analyst has made adjustments, the mask is used to create a synoptic, geographically accurate tire-pile survey map, which can be overlaid with a road map and/or any other map or set of georeferenced data, according to a customer's preferences.

Monitoring by Use of Clusters of Sensor-Data Vectors

Incoming data vectors are compared with clustered vectors representative of normal operation.

Ames Research Center, Moffett Field, California

The inductive monitoring system (IMS) is a system of computer hardware and software for automated monitoring of the performance, operational condition, physical integrity, and other aspects of the "health" of a complex engineering system (e.g., an industrial process line or a spacecraft). The input to the IMS consists of streams of digitized readings from sensors in the monitored system. The IMS determines the type and amount of any deviation of the monitored system from a nominal or normal ("healthy") condition on the basis of a comparison between (1) vectors constructed from the incoming sensor data and (2) corresponding vectors in a database of nominal or normal behavior. The term "inductive" reflects the use of a process reminiscent of tra-

ditional mathematical induction to "learn" about normal operation and build the nominal-condition database. The IMS offers two major advantages over prior computational monitoring systems: The computational burden of the IMS is significantly smaller, and there is no need for abnormal-condition sensor data for training the IMS to recognize abnormal conditions.

The figure schematically depicts the relationships among the computational processes effected by the IMS. Training sensor data are gathered during normal operation of the monitored system, detailed computational simulation of operation of the monitored system, or both. The training data are formed into vectors that are used to generate the database. The vectors in the database are

clustered into regions that represent normal or nominal operation. Once the database has been generated, the IMS compares the vectors of incoming sensor data with vectors representative of the clusters. The monitored system is deemed to be operating normally or abnormally, depending on whether the vector of incoming sensor data is or is not, respectively, sufficiently close to one of the clusters. For this purpose, a distance between two vectors is calculated by a suitable metric (e.g., Euclidean distance) and "sufficiently close" signifies lying at a distance less than a specified threshold value.

It must be emphasized that although the IMS is intended to detect off-nominal or abnormal performance or health, it is not necessarily capable of perform-